A multiple criteria evaluation typology of environmental management problems

Janssen, R.; Nijkamp, P.

1985

SERIE RESEARCHMEMORANDA

A MULTIPLE CRITERIA EVALUATION TYPOLOGY OF ENVIRONMENTAL MANAGEMENT PROBLEMS

Ron Janssen
Peter Nijkamp

Researchmemorandum 1985-1 Jan. 1985

VRIJE UNIVERSITEIT
EKONOMISCHE FAKULTEIT
AMSTERDAM

A MULTIPLE CRITERIA EVALUATION TYPOLOGY OF ENVIRONMENTAL MANAGEMENT PROBLEMS

Ron Janssen
Ministry of Housing, Physical Planning and Environmental Management
The Hague

Peter Nijkamp
Department of Economics
Free University
Amsterdam

Paper presented at the Conference
on Multiple Criteria Decision-Making,
Cleveland, Ohio, May, 1984.

ABSTRACT

In the past much attention has been devoted to the design of multiple criteria methods without much concern regarding the specific conditions under which these methods may be applied.

In the present paper a reverse approach is adopted. First, a specific field of application is defined, viz., environmental management. Then the characteristics of environmental issues and environmental management problems are described based on a systematic typology of environmental problems. Next, for each class of environmental (management) problems the specific requirements, desires or criteria are specified in order to be able to apply evaluation methods to these problems.

Finally, a systematic judgement of the existing classes of multiple criteria evaluation methods is made in order to select appropriate (classes of) evaluation methods for specific classes of environmental management problems.

This paper leads thus to a classification of discrete and continuous multiple criteria evaluation methods on the basis of a systematic typological approach to environmental policy analysis.

INTRODUCTION

In the past decade, a wide variety of multiple criteria evaluation methods has been designed, which aimed at structuring, systematizing and judging complex decision methods marked by multiple dimensions. In this period, the general principle for rationalizing such complex choice and tradeoff problems was based on a straightforward approach: given (i) a certain evaluation problem and (ii) a certain specific evaluation technique, what is the most plausible outcome for the decision problem concerned?

An overview of the field of application of evaluation methods demonstrates a great diversity of these methods, ranging from cost-benefit analysis and multiple criteria analysis to participation and interactive policy methods. In many cases, decision problems had to be reformulated or transformed in order to let them fit the specific requirements imposed by the evaluation technique at hand. This 'torturing of data' may lead to a 'tailor-made' evaluation problem, but neglects the specific characteristics of practical decision problems.

Surprisingly, only a few attempts have been made to regard the choice of a specific evaluation method for a practical decision problem as a multiple criteria choice problem (see also Rietveld, 1980). The solution to this problem will require a closer analysis of a predefined field of policy analysis in order to develop an operational research methodology. The field which will be examined in greater detail here is environmental management and environmental policy analysis (see also Nijkamp, 1981). Therefore, in the present paper we will focus attention on a reverse and problem-oriented approach: which are the specific multidimensional features of various environmental management problems and what do these features mean for the choice of an appropriate evaluation method?

A further analysis of these questions would require a systematic inventory and typology of environmental management problems, based on a set of relevant classification principles. In this paper, the following steps have been undertaken:

- inventory and classification of environmental management problems (air quality management, water management, waste management, etc.)
- typology of policy relevant attributes of environmental management problems (information need, trade-off analysis, conflict analysis, etc.)
- identification of sets of criteria to be fulfilled by the evaluation method(s) selected for the treatment of a specific environmental evaluation problem
- confrontation of these criteria with various available evaluation methods in order to identify classes of evaluation methods that are appropriate for predefined sets of environmental management problems.

IDENTIFICATION OF THE ACTIVITIES PROFILE

Methodology

Environmental management problems are glaring examples of unpriced and conflictuous decision problems which may be analysed by means of multiple criteria decision techniques. However, not all multiple criteria methods are suitable for all environmental management problems. Therefore, two research lines have to be followed: (i) the identification of a set of activities (traffic, resource extraction, industry, etc.) which are connected with environmental problems and/or policies, and (ii) the identification of a requirements profile for the evaluation method in regard to each class of activities. By combining the activity vector with the requirements profile, one may examine whether or not for a certain class of activities one or more appropriate evaluation methods are available. In the present section, we will address the issue of the activities profile.

Evaluation problems can be distinguished inter alia on the basis of the following features (see Figure 1.).

- the attributes of the activities to be evaluated (for instance, the construction of a motorway or the introduction of a so-called 'bubble'-policy)
- the characteristics of the effects caused by the activities (for instance, local or spill-over effects, short-term or long-term effects)
- the nature of the decision structure related to the activity (for instance, a hierarchical institutionalized policy structure, participatory decisions, etc.).

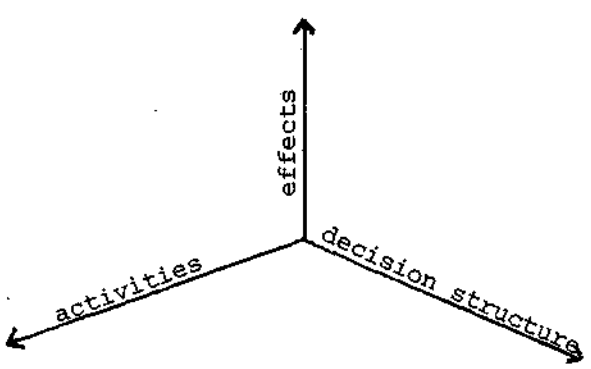

Figure 1. Three dimensions of environmental evaluation problems.

In the framework of the present paper on environmental management issues, activities will only be included if:

- these activities cause a relevant environmental impact
- the government may exert an influence on the implementation of these activities (changes, regulations, etc.).

Furthermore, beside environmental effects, the non-environmental consequences will only be included if they play a role in the trade-off of the environmental policies concerned.

The Activities Profile

The identification of classes of activities takes place on the basis of comparable environmental effects and comparable policy measures.

The following classes of activities have been distinguished:

1. transport and transport infrastructure
2. land use and reconstruction of rural areas
3. urban land use, building and reconstruction
4. urban management and use
5. resource extraction
6. waste disposal
7. industry
8. environmental upgrading.

A further subdivision of these activities can be made on the basis of the nature of these activities and of their spatial scale.

The nature of these activities is determined by the range of effects, the level of precision and the extent of policy intervention. Three categories may be mentioned here:

- project : The activity can clearly be identified and demarcated in space and time (for instance, the construction of an industrial plant). Projects may be further subdivided into:
  - direct governmental influence (for instance, railway construction)
  - indirect governmental influence (for instance, subsidies on a new environmental technology).
- plan : The activity is made up by a coherent set of relatively less precisely defined sub-activities with a joint aim (for instance, a structure plan for physical planning).
- regulation : The activity comprises all measures that may have an indirect impact (mainly via related activities) on environmental quality (for instance, environmental standards, charges, subsidies).

Both plans and regulations may have a sector nature or a facet nature.

The spatial scale of activities may relate to:

- international activities (cross-boundary transportation, e.g.)
- national activities (environmental impact regulation, e.g.)
- regional activities (location of an industry, e.g.)
- local activities (urban traffic rules, e.g.).

By combining now the attributes characterizing the nature of activities with the spatial scale, one may construct an activities profile (see Table 1.). Table 1 contains a representative - though not exhaustive - set of activities which are judged to be relevant in the framework of a typological approach.

The Effects

Effect analysis aims at assessing the foreseeable consequences of various activities. The following effects in the framework of environmental management are relevant:

A. environmental effects : (1) soil and ground water
(2) surface water
(3) air
(4) plants
(5) animals
(6) landscape
(7) noise annoyance
(8) climate

B. non-environmental effects : (9) employment
(10) income
(11) accessibility
(12) housing market
(13) energy use
(14) facilities
(15) security
(16) health.

The effects can also be classified according to their features:

A. temporal effects : (1) unique
(2) repetitive
(3) continuous short-term
(4) continuous long-term

B. spatial aspects : (5) stationary
(6) mobile
(7) international
(8) national
(9) regional
(10) local

C. remaining features : (11) formal regulations applicable
(12) formal regulations not applicable
(13) marginal impact of effects
(14) non-marginal impact of effects.

It is clear that - as the next step of the typological approach - an impact (or effect) table can be constructed which comprises all activities and their expected

Class of activities	Activities	project		plan		regulation						
		dir.publ.interference	indir.publ.interference	facet policy	sector policy	facet policy	sector policy	international	national	regional	local	
1. Transport and transport infrastructure	1.1 highway construction	x							x			
	1.2 integrated traffic plan				x						x	
	1.3 reconstruction rivers and canals	x								x		
	1.4 construction of powerlines	x								x		
	1.5 expansion of air transport		x					x				
	1.6 transport dangerous goods		x						x			
	1.7 changing speed limits						x		x			
	1.8 LPG storage		x						x			
2. Land use and reconstruction of rural areas	2.1 land reallocation plan				x						x	
	2.2 purchase of agricultural surplus (EC)						x	x				
	2.3 construction recreation site		x								x	
	2.4 assignment of natural park					x				x		
	2.5 assignment of military training areas			x					x			
	2.6 large-scale supermarkets out of town		x							x		
	2.7 policy plan rural areas			x							x	
3. Urban land use, building and reconstruction	3.1 urban extension	x									x	
	3.2 office building		x								x	
	3.3 urban renewal						x		x			
	3.4 policy plan urban areas					x					x	
	3.5 construction of industrial areas	x								x		
4. Water management and use	4.1 construction of dikes and dams	x							x	x		
	4.2 land reclamation	x							x			
	4.3 water extraction	x								x		
	4.4 policy plan water quality				x					x		
	4.5 water infiltration	x								x		
	4.6 discharge of hazardous waste					x		x	x			

Table 1. The activities profile.

Class of activities	Activities	project		plan		regulation					
		dir.publ.interference	indir.publ.interference	facet policy	sector policy	facet policy	sector policy	international	national	regional	local
5. Resource extraction	5.1 sand extraction		x								x
	5.2 gravel extraction		x							x	
	5.3 extraction of natural gas		x						x		
	5.4 oil extraction		x						x		
6. Waste treatment	6.1 dumping ground for waste	x									x
	6.2 burning installation for waste	x									x
	6.3 regional policy plan waste treatment				x					x	
	6.4 underground dumping chemical discharges		x							x	
	6.5 processing nuclear waste		x						x		
	6.6 regulation waste discharge						x		x		
7. Industry	7.1 oil refinery		x							x	
	7.2 chemical industry		x							x	
	7.3 steel industry		x							x	
	7.4 regulation of investments						x		x	x	
	7.5 limitation of steel production (EC)						x	x			
	7.6 nuclear power plants	x							x		
	7.7 subsidies on energy saving					x			x		
8. Environmental upgrading	8.1 regulation soil protection					x			x		
	8.2 environment impact analysis					x			x		
	8.3 regulation noise annoyance					x			x		
	8.4 regulation air pollution					x			x		
	8.5 regulation of food quality						x		x		
	8.6 regulation via nuisance act					x					x

Table 1. The activities profile (continued).

consequences (see Table 2).

The Decision Structure

The decision problem in the framework of environmental management may have the following characteristics:

A. alternatives :
- discrete number / continuous
- point alternatives / sequential alternatives
- mutually exclusive alternatives / mutually non-exclusive alternatives

B. information content :
- quantitative / qualitative
- certain / uncertain
- extensive / limited
- complete / incomplete.

The decision space of environmental management problems can be characterized by:

A. the institutional structure :
- international / national / regional / local
- single objective / multiple objectives
- hierarchical / negotiation / informal
- routine / non-routine
- analytical / heuristic

B. the aim of the evaluation :
- ex ante evaluation / ex post evaluation
- internal communication / external communication
- identification of one alternative / identification of feasible alternatives / ranking of all alternatives.

Clearly, the above-mentioned features can also be included in a matrix that combines activities and characteristics of the decision problem at hand, but for the sake of brevity this matrix will not be presented here (see Janssen, 1984b).

activities	classes of effects																features													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.1	x		x	x	x	x	x		x		x				x	x	x			x	x	x		x	x	x	x	x	x	
1.2			x				x		x		x				x	x				x	x					x	x	x	x	
1.3	x	x		x	x	x			x		x		x		x		x			x	x	x			x			x	x	
1.4					x	x			x								x			x	x					x		x	x	
1.5			x				x		x		x		x			x				x	x				x	x	x	x	x	
1.6	x								x						x	x		x				x					x	x	x	
1.7							x				x		x		x	x				x	x			x			x		x	
1.8		x							x						x			x			x					x	x	x		x
2.1	x	x		x	x	x			x	x								x	x	x	x				x	x	x	x	x	
2.2	x	x		x	x	x			x	x			x						x	x		x	x	x	x	x	x	x		x
2.3					x	x			x					x			x								x	x		x	x	
2.4				x	x	x			x	x				x						x					x	x		x		x
2.5					x	x	x								x				x		x			x			x	x		x
2.6						x			x					x			x				x				x	x		x		x
2.7						x													x		x				x			x		x
3.1	x					x			x			x					x				x					x		x		x
3.2						x			x								x				x					x	x	x	x	
3.3									x			x		x						x	x					x	x	x		x
3.4						x						x							x		x					x		x		x
3.5	x					x			x								x				x					x		x		x
4.1		x				x			x						x		x			x	x	x			x		x	x		x
4.2	x	x				x			x								x			x	x	x			x			x		x
4.3	x	x		x	x									x						x		x			x			x	x	
4.4		x														x				x		x			x		x		x	
4.5	x	x		x	x															x		x			x			x	x	
4.6	x	x							x						x	x				x		x				x	x	x		x
5.1	x			x	x	x	x		x	x										x	x	x			x	x		x		
5.2	x			x	x	x	x		x	x										x	x	x			x	x		x		
5.3	x				x	x			x	x										x	x				x	x	x	x	x	
5.4		x			x				x	x										x		x			x	x	x	x	x	
6.1	x			x	x	x			x								x			x	x	x				x	x	x	x	
6.2			x			x			x				x				x			x	x	x			x	x	x	x	x	
6.3	x		x	x	x	x		x						x	x	x				x		x			x		x	x		x
6.4	x								x						x	x				x		x			x		x	x		x
6.5		x													x	x				x		x			x		x			x
6.6	x		x												x	x				x		x		x			x			x
7.1			x		x	x			x	x			x				x			x	x	x			x		x	x		x
7.2	x	x	x	x	x	x		x	x	x			x		x	x	x			x	x	x			x		x	x		x
7.3	x		x	x	x	x	x		x	x						x	x			x	x	x			x		x	x		x
7.4	x	x	x			x	x		x	x						x				x		x			x		x	x		x
7.5	x		x	x	x	x		x	x	x						x				x		x		x	x		x	x		x
7.6		x				x			x						x	x				x	x	x		x	x		x	x		x
7.7			x						x				x							x		x		x	x			x	x	
8.1	x			x					x						x	x				x	x				x	x		x		x
8.2	x	x	x	x	x	x	x		x			x				x			x	x	x			x	x	x		x		x
8.3							x		x			x							x		x					x		x		x
8.4			x	x		x			x						x				x		x			x				x		x
8.5															x	x			x	x		x		x			x			x
8.6	x	x	x	x	x		x								x	x			x			x				x	x		x	

Table 2. Impact matrix.

SELECTION OF AN EVALUATION METHOD

In this section the features of environmental problems listed above are translated into explicit criteria for selecting evaluation methods (see also Lichfield, 1975; Rietveld, 1980; McAllister, 1980; Voogd, 1983; Janssen, 1984a). By comparing these criteria with features of available methods insight is given into the relative usefulness of different methods for different problems.

Selection criteria are divided into first and second order criteria (cf. Duckstein et al., 1981).

- First order criteria are mandatory binary criteria for the selection of an evaluation method; if a method does not comply with all first order criteria which are relevant to a certain problem this method cannot be applied to this problem.
- Second order criteria are not a priori mandatory criteria for the selection of an evaluation method. One tries to find a method which complies with as many second order criteria as possible but only a few, depending on the actual circumstances, will in practice function as mandatory criteria.

Part of the selection criteria are relevant to all evaluation problems. Some examples of these general criteria are listed in Table 3. Most selection criteria, however, are linked to specific features of environmental problems which means that methods can only be judged in relation to the problem which they are intended to solve. For this reason in Table 4, 5, and 6 the selection criteria related to a number of possible environmental evaluation problems are compared with the features of a number of available evaluation methods. If a method in its basic form complies with a criterion this is indicated with an x.

G1	The evaluation method (EM) must be able to make a consistent trade-off between different policy goals.
G2	The EM must produce results that are understandable to the decision-makers involved.
G3	The EM must be able to process information measured in different dimensions in a comparable way.
G4	The principles and assumptions of the EM must be explicable to decision-makers involved.

Table 3. General selection criteria.

If it is possible to extend a method in a way that makes it comply with a criterion this is indicated with an 0.

Criterion	1.7 changing speed limits	2.2 buying of agricult. surplus	4.3 water extraction	4.4 policy plan water quality	4.5 water infiltration	5.1 sand extraction	5.2 gravel extraction	5.3 natural gas extraction	5.4 oil extraction	7.3 macro-econ. sectoral policy	7.5 limitation steel prod. (EC)	7.7 subs. for energy conservation	1. explicit utility functions	2. implicit utility functions	3. restricted utility functions	4. hierarch. decision structures	5. goal programming	6. gaming methods	7. ideal point methods	8. interactive decision methods
S1 The EM must be based on a continuous decision function	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
S2 The EM must be based on a decision function for discrete choices																				
S3 The EM must be able to handle quantitative information in an efficient and methodologically sound way	x	x	x	x	x				x		x	x	x	x	x	x	x	x	x	x
S4 The EM should be able to handle qualitative information or a combination of qualitative and quantitative inform.in an efficient and methodolog.sound way						x	x	x		x						x				x
S5 The EM must be able to process uncertain information	x								x	x		x	o	x	o	o	o			x
S6 The EM must be able to process effects occurring on different points in time													x	o	x	o	x	o	x	x
S7 The EM must be able to process effects which occur continuously over time	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o	x	x	x	x
S8 The EM must be able to include the spatial pattern of the effects		x	x	x	x	x	x		x	x	x	x	o	o	x	x	x	x	x	x
S1 The EM should be able to include effects at different spatial scales		x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
S2 The EM must allow for the introduction of constraints	x	x		x				x	x	x	x		o	o	x	x	x	x	x	x
S3 The EM must be able to relate the size of an effect to the importance of an effect	x		x	x	x			x	x			x	x	x	x	x	x	x	x	x
S4 The EM must be able to relate the importance of an effect to the importance of all other effects		x				x	x			x	x		x	x	x	x	x	x	x	x
S5 The EM must be able to include information on past decisions in the analysis		x	x			x	x	x	x	x	x	x	x	x	x	x				x
S6 The EM must be able to include alternatives both separately and in combination		x	x		x	x	x	x	x	x			x		x	x	x	x	x	x
S7 The EM must take account of the decision maker's attitude to risk	x		x	x	x					x		x		x			x			x
S8 The EM must not be based on a algorithm of which the amount of required calculations increases exponentially with the amount of data			x	x	x	x	x				x		x	x	x	x	x	x	x	x
S9 The EM must be able to integrate decisions at different decision levels																	x	x	x	x
S10 The EM must be able to incorporate easily information from the past	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
S11 The EM must stimulate the imagination of the decision maker				x						x										x
S12 The EM may not include implicit subjective choices and must be repeatable	x					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
S13 The EM must be based on a decision rule related to optimizing behaviour	x	x	x	x	x							x	x	x		x	x	x	x	x
S14 The EM must be based on a decision rule related to satisficing behaviour										x	x				x	o	o	o	o	x
S15 The EM should not require a priori information on preferences and should not provide to detailed results															o		x	x	x	x
S16 The EM must be simple and applicable without the use of a computer				x		x	x									x				o
S17 The application of the EM must be cheap and not time consuming				x		x	x									x				

Table 4. Appraisal of continuous evaluation methods using specific selection criteria for continuous evaluation problems.

Criteria	Activities: 1.1 power lines	1.5 expansion of air transport	1.6 transport of dangerous goods	1.8 LPG storage	6.3 reg.waste disposal plan	6.4 underground disposal of chemical waste	6.5 processing of radio-active waste	6.6 reg. waste of discharge	7.4 regulation of investments	8.1 groundwater protection law	8.3 noise abatement law	8.4 air pollution legislation	8.6 licencing installations under Nuisance Act	Evaluation methods: 1. cost benefit analysis	2. cost effectiveness analysis	3. planning balance sheet method	4. shadow proj. approach	5. goals achievement matrix	6. expected value method	7. discrepancy analysis	8. concordance analysis	9. graphical presentation
S1 The EM must be based on a continuous decision function																						
S2 The EM must be based on a decision function for discrete choices	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
S3 The EM must be able to handle quantitative information in an efficient and methodologically sound way	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
S4 The EM should be able to handle qualitative information or a combination of qualitative and quantitative inf. in an efficient and methodolog. sound way																						
S5 The EM must be able to process uncertain information	x		x	x	x	x	x	x		x				x	x			x	x	o	o	x
S6 The EM must be able to process effects occurring on different points in time			x	x										x			x	x	x	o	o	x
S7 The EM must be able to process effects which occur continuously over time		x			x	x	x	x	x	x	x	x	x	x	x		x	o	o	o	o	o
S8 The EM must be able to include the spatial pattern of the effects			x		x	x	x	x	x				x		x	x	x		o			o
<u>S1</u> The EM should be able to include effects at different spatial scales		x								x				x	x	x	x	x	x			
<u>S2</u> The EM must allow for the introduction of constraints		x	x	x	x	x							x	x	x							
<u>S3</u> The EM must be able to relate the size of an effect to the importance of an effect	x	x	x										x	x	x			x	x			x
<u>S4</u> The EM must be able to relate the importance of an effect to the importance of all other effects				x	x	x				x	x	x										
<u>S5</u> The EM must be able to include information on past decisions in the analysis		x				x							x	x	x		x					
<u>S6</u> The EM must be able to include alternatives both separately and in combination	x	x		x		x								x		x	x	x	x			x
<u>S7</u> The EM must take account of the decision maker's attitude to risk	x		x	x	x	x				x	x											
<u>S8</u> The EM must <u>not</u> be based on an algorithm of which the amount of required calculations increased exponentially with the amount of data					x									x	x	x	x	x	x	x	x	
<u>S9</u> The EM must be able to integrate decisions at different dec. levels	x					x								x		x	x	x				
<u>S10</u> The EM must be able to incorporate easily information from the past	x	x	x			x								x			x					x
<u>S11</u> The EM must stimulate the imagination of the decision maker				x	x					x	x	x	x			x	x	x		x		
<u>S12</u> The EM may <u>not</u> include implicit subjective choices and must be repeatable	x	x		x	x	x				x	x	x	x		x				x	x		x
<u>S13</u> The EM must be based on a decision rule related to optimizing behav.					x					x	x	x	x	x	x	x		x	x	x	x	x
<u>S14</u> The EM must be based on a decision rule rel.to satisficing behaviour	x	x	x	x													x					
<u>S15</u> The EM should <u>not</u> require a priori inform. on preferences and should not provide to detailed results														x	x	x		x				
<u>S16</u> The EM must be simple and applicable without the use of a computer	x	x			x								x		x	x		x	x	x	x	x
<u>S17</u> The application of the EM must be cheap and not time consuming	x	x	x		x								x		x			x	x	x	x	x

Table 5. Appraisal of discrete quantitative evaluation methods using specific selection criteria for discrete evaluation problems with quantitative information.

Activities	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17
1.1 highway construction		x		x	x		x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
1.2 traffic plan		x		x	x		x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
1.3 change of riverbed		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
2.1 land reallocation plan		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
2.3 constr.of recreation side		x		x		x	x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
2.4 design.nature prot.area		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
2.5 ass.mil.training areas		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
2.6 large-scale supermarkets		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
2.7 rural physical plan		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
3.1 urban expansion		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
3.2 construction of offices		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
3.3 urban renewal laws		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
3.4 policy plan urban areas		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
3.5 constru.industrial area		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
4.1 constr.of dikes and dams		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
4.2 constr. of new polders		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
4.6 law disposal dang.goods		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
6.1 solid waste disposal		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
6.2 incinerators		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
7.1 oil refinery		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
7.2 chemical industry		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
7.6 nuclear power plants		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
8.2 envir.impact assessment		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
8.5 regul. food quality		x		x			x			x	x	x	x	x	x	x	x	x	x	x	x			x	x
Evaluation methods																									
1. concordance analysis	x			x	o	o	o	o																	
2. frequency method	x			x	o	o	o																		
3. lexicographic ordening	x			x	o	o	o																		
4. permutation method	x			x	o	o	o	o																	
5. own value method	x			x	o	o	o	o																	
6. regime method	x			x	o	o	o	o																	
7. multidimensional scaling	x			x	o	o	o	o																	
8. metagame method	x			x	o	o	o	o																	
9. mixed data method	x			x	o	o	o	o																	
10. trichotomic choice method	x			x	o	o	o	o																	
11. score card method	x			x	o	o	o	o																	
12. key issue matrix	x			x	o	o	o	o																	

Table 6. Appraisal of discrete qualitative evaluation methods using specific selection criteria for discrete evaluation problems with qualitative information.

In this study evaluation problems are divided into three main categories:

- evaluation problems with a continuous set of alternatives and quantitative information (Table 4.)
- evaluation problems with a discrete set of alternatives and quantitative information (Table 5.)
- evaluation problems with a discrete set of alternatives and qualitative information (Table 6.).

Evaluation methods are divided according to these three categories. Most of the methods listed are well-known and will not be described here. Descriptions can be found in Hwang and Masud (1979), Rietveld (1980), Nijkamp (1980), Voogd (1983), Chankong and Haimes (1983), and Janssen (1984a, 1984b).

It can be concluded from Tables 4, 5, and 6 that most methods in their basic form are not able to deal with the time, space and uncertainty features of the listed problems. It can also be concluded that in all problems a number of second order criteria will not be fulfilled.

The procedure of selecting an evaluation method is further illustrated by the following case study.

CASE STUDY

The procedure developed in this study for characterizing environmental problems and selecting evaluation methods according to these characteristics will be illustrated by means of an evaluation study carried out by the Rand Corporation and submitted to the Dutch Government.

As part of the Delta Plan designed to protect the Dutch province of Zeeland and its hinterland against flooding a decision had to be taken on how to control the Oosterschelde estuary (see Figure 2.). The original plan was to close off the Oosterschelde with a dike. Following strong protest amongst others from environmentalist and fishermen two other less environmental damaging alternatives were developed.

A decision therefore had to be taken between three alternatives:

- construction of a closed dam at the mouth of the Oosterschelde
- construction of a barrier which is normally open but can be closed if necessary
- strengthing and raising of existing dikes around the Oosterschelde.

In terms of this study this is an evaluation problem with a discrete set of few alternatives. Some of the other features of this problem will be listed below. Each alternative gives rise to a wide range of effects which differ considerably in several respects. These effects include effects on safety, the environment, fisheries, recreation, water transports and the economy. Some of these effects are short term, for example reduction of the chance of flooding during construction. Reduction of the chance of flooding after construction has been completed is on the contrary a long-

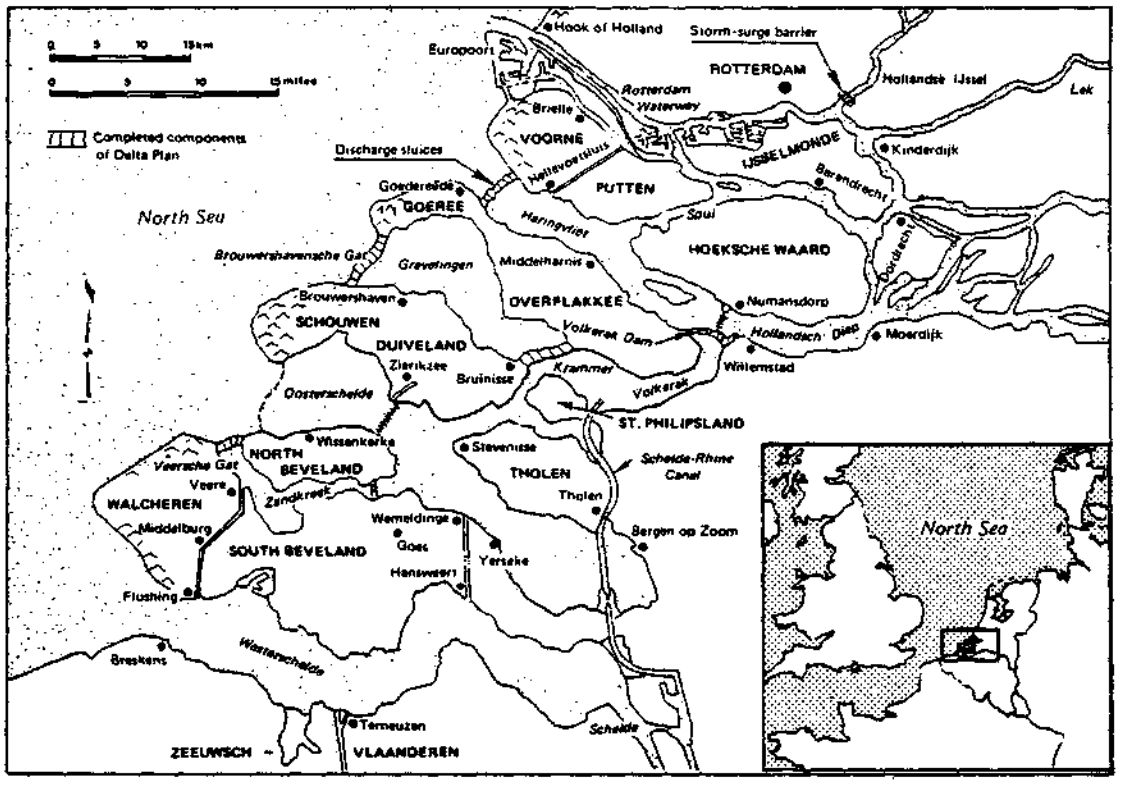

Figure 2. The Delta-Works

term effect. Some of the effects, e.g., the change in landscape, can be predicted with certainty; others, such as the chance of flooding due to an extremely heavy storm are uncertain with a known probability distribution. Most of the ecological effects, however, are uncertain with an unknown probability distribution.

The available information is partly quantitative (monetary and non-monetary) and partly qualitative (ordinal and nominal). The decision is made in negotiation between different ministries (Environment, Transport, Economics, Finance). The decision process is carefully followed by a variety of environmental and economic interest groups.

The features of this evaluation problem are summarized in Table 7. The selection criteria which are linked to these features are listed in Table 8. Table 8 can be used for the selection of an appropriate evaluation method for this problem.

The for this problem relevant first order criteria are shaded on the left hand side of Table 8. It can be seen that no method in its basic form complies with all these criteria. Most of the methods listed however can be extended in a way which makes application of these methods on this problem possible.

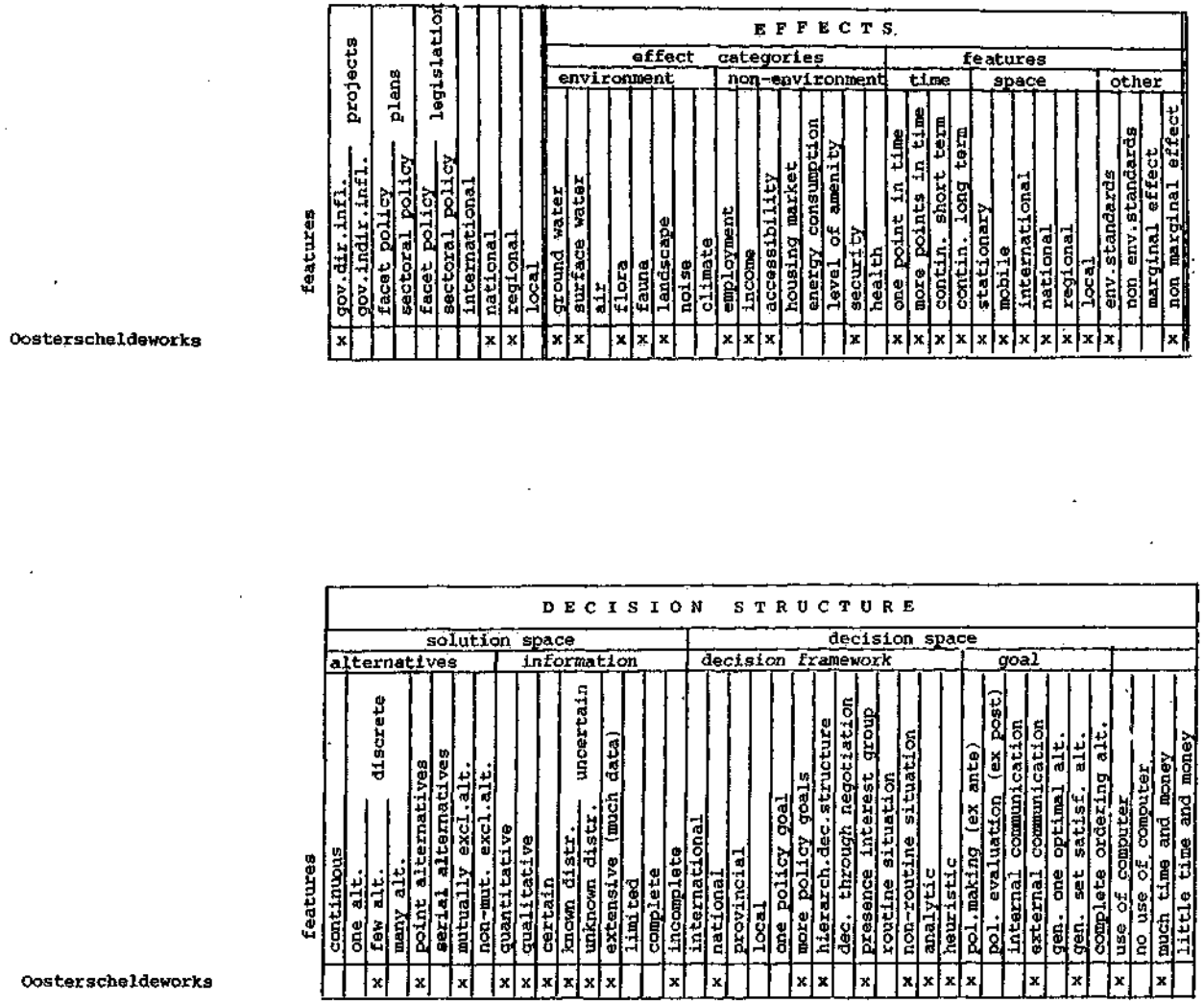

Table 7. *The features of the evaluation problem: Protecting an estuary from floods.*

Evaluation methods																		
1. concordance analysis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2. frequency method																		
3. lexicographic ordering																		
4. permutation method																		
5. own value method																		
6. regime method																		
7. multidimensional scaling																		
8. metagame method																		
9. mixed data method																		
10. trichotomic choice method																		
11. score card method																		
12. key issue matrix																		
Oosterschelde	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Activity	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
S1 The EM must be based on a continuous decision function																		
S2 The EM must be based on a decision function for discrete choices	x																	
S3 The EM must be able to handle quantitative information in an efficient and methodologically sound way																		
S4 The EM should be able to handle qualitative information or a combination of qualitative and quantitative inf.in an efficient and methodolog.sound way	x																	
S5 The EM must be able to process uncertain information	x																	
S6 The EM must be able to process effects occurring on different points in time	x																	
S7 The EM must be able to process effects which occur continuously over time	x																	
S8 The EM must be able to include the spatial pattern of the effects	x																	
S1 The EM should be able to include effects at different spatial scales	x																	
S2 The EM must allow for the introduction of constraints	x																	
S3 The EM must be able to relate the size of an effect to the importance of an effect	x																	
S4 The EM must be able to relate the importance of an effect to the importance of all other effects	x																	
S5 The EM must be able to include information on past decisions in the analysis	x																	
S6 The EM must be able to include alternatives both separately and in combination																		
S7 The EM must take account of the decision maker's attitude to risk	x																	
S8 The EM must not be based on an algorithm of which the amount of required calculations increases exponentially with the amount of data																		
S9 The EM must be able to integrate decisions at different decision levels																		
S10 The EM must be able to incorporate easily information from the past																		
S11 The EM must stimulate the imagination of the decision maker	x																	
S12 The EM may not include implicit subjective choices and must be repeatable	x																	
S13 The EM must be based on a decision rule related to optimizing behaviour																		
S14 The EM must be based on a decision rule related to satisficing behaviour	x																	
S15 The EM should not require a priori information on preferences and should not provide to detailed results	x																	
S16 The EM must be simple and applicable without the use of a computer																		
S17 The application of the EM must be cheap and not time consuming																		

Table 8. The features of the available evaluation methods.

From the right hand side of Table 8 one can conclude that no evaluation method meets all relevant second order criteria. In this case the following two of the second order criteria seem to be of special relevance:

- S12. The evaluation method may not include implicit subjective choices and must be repeatable.

This criterion is of special importance because a wide range of people and groups with many different views and interests are involved in the decision-making process, both inside and outside the government.

- S15. The evaluation method should not require a priori information on preferences and should not provide too detailed results.

This criterion is particularly important because in a decision which is to be made through negotiation, such as this, people involved will be unwilling to express their preferences beforehand.

The features of evaluation methods corresponding to criterion S12 and S15 are shaded in Table 8. One can see that according to these criteria the score card method and the key issue matrix can be applied to this problem. These methods also comply with the greatest number of other second order criteria.

Score card methods aim at presenting available information in such a way that the alternatives can be judged without applying arithmatics to these scores. The scores are listed in a score card and clarified by the use of graphics. Score cards can contain all types of information (cardinal, ordinal, nominal). By adding a commentary column an indication of the level of certainty in predicting the effects can be given. The Rand Corporation also used a score card in this case. As an illustration part of this score card is shown in Table 9.

	Security		
Long run:			
Land flooded (ha) in 1/4000 storm, L(90)[a]	0	0	400
Technical uncertainty	None	Scour	Dikes
Transition period expected damage:			
Land flooded (ha)	430	200	330
Value of real property flooded (DFL million)	50	20	60
Number of people at risk	800	360	970

Table 9. A score card.

The key issue method, which can be seen as a variant of the score card method, also aims to make a judgement without applying arithmatic to the scores. Reduction of the amount of information presented takes place in three steps:

1. cross out inefficient alternatives;
2. cross out alternatives which cause effects that exceed some constraints such as environmental standards or the available budget;
3. cross out effects that do not differentiate between the alternatives or are due to their relative size of minor importance for the decision.

The method as used by Rand is in fact a combination of both methods. First the number of alternatives was reduced to three and different score cards were drawn up for different groups of effects. Secondly a summary of score cards was drawn up listing only the most important effects.

CONCLUSION

Evaluation is a way of rationalizing and justifying complex decisions. Usually, however, a friction does exist between a specific practical evaluation problem and the available specific evaluation technique. This paper has made an attempt at bridging this gap by means of a systematic typological approach.

In regard to the characteristics of environmental management problems, the following conclusions can be drawn:

- each activity causes a diversity of environmental and non-environmental effects
- the majority of evaluation problems is marked by a discrete set of alternative choice options
- the majority of evaluation problems is marked by both quantitative and qualitative information
- lack of certainty and predictability is an important feature of many effects
- the majority of evaluation problems is marked by conflicting objectives
- external interest groups play an important role in many evaluation problems
- evaluation is a matter of both an analytical and a heuristic policy style.

Given all activities, their features and effects, it appears to be possible to identify a set of appropriate techniques for a specific type of evaluation problems by means of the typological analysis based on the successive matrices.

Finally, also several shortcomings have been identified in the use of evaluation methods, viz. the lack of integration of time and space and the lack of insight into uncertainty. In this respect, the design of appropriate information systems and decision support systems is a prerequisite for a further progress in the evaluation methodology of environmental management.

REFERENCES

Changkong, V., Y.Y. Haimes, 1983, Multi-objective Decision Making, Theory and Methodology, North-Holland Publ. Co., Amsterdam.
Duckstein, L., I. Bogardi, M.E. Gershon, 1981, Multi-objective Decision Making: Model Choice, Working Paper IIASA, Laxenburg.
Hwang, C., and A. Masud (eds.), Multiple Objective Decision Making, Springer, Berlin, 1979.
Janssen, R., 1984a, Beoordeling van de gevolgen van ruilverkaveling met behulp van multi-criteria analyse, National Institute for Forestry and Landscape Research: 'De Dorschkamp', Wageningen.
Janssen, R., 1984b, Evaluatiemethoden ten behoeve van het Milieubeleid en -beheer, Economic and Social Institute, Free University, Amsterdam.
Lichfield, N., P. Kettle, M. Whitbread, 1975, Evaluation in the Planning Process, Pergamon Press, Oxford.
McAllister, D.M., 1980, Evaluation in Environmental Planning, MIT Press, Cambridge (Mass.).
Nijkamp, P., 1981, Environmental Policy Analysis, Wiley/Chichester, New York.
Rand Corporation, 1977, Protecting an Estuary from Floods: A Policy Analysis of the Oosterschelde, Rand Corporation, Santa Monica.
Rietveld, P., 1980, Multiple Objective Decision Methods and Regional Planning, North-Holland Publ. Co., Amsterdam.
Voogd, H., 1983, Multicriteria Evaluation for Urban and Regional Planning, Pion, London.